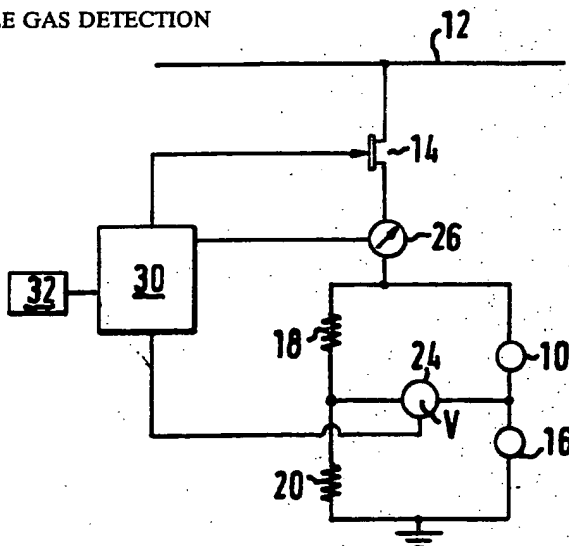




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(54) Title: COMBUSTIBLE GAS DETECTION



(57) Abstract

The invention provides a method and apparatus for detecting combustible gases in an atmosphere and is particularly concerned with the detection of two or more combustible gases in the atmosphere. The detection is achieved by measuring the resistance of a heated pellistor (10) consisting of an electrical resistance wire that is in thermal contact with a catalyst on which the combustible gases can combust; the combustion results in an increase in the temperature of the resistance wire and so changes the resistance of the wire in accordance with the amount of combustible gas in the atmosphere; the resistance may be measured by incorporating the pellistor into a bridge (10, 16, 18, 20). Difficulties arise when two or more combustible gases are present since different gases produce different temperature rises. The present invention alters the potential applied across the wire during the course of measurement by a voltage pulse generator (14), thereby also altering the temperature of the catalyst, and it is possible either to resolve the resulting resistance readings into resistance readings for the individual combustible gases or to integrate the resistance readings over time so that the signal produced will be approximately the same for unit amounts of many combustible gases.

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COMBUSTIBLE GAS DETECTIONTECHNICAL FIELD

The present invention relates to the detection of
5 combustible gas.

BACKGROUND ART

Combustible gases can be detected by a device called a
'pellistor' comprises an electrical resistance wire in thermal
contact with a catalyst that catalyses the decomposition of the
10 combustible material. The catalyst may be deposited directly on
the resistance wire or it may be deposited on the surface of a
bead, e.g. of refractory material, through which the resistance
wire passes, the part of the wire lying within the bead is
usually coiled to provide the pellistor with a sufficient
15 electrical resistance; by passing an electrical current through
the wire the pellistor can be heated to a temperature at which
the combustible gas will decompose on the catalyst surface. The
current flowing through the wire is measured and provides a
measure of the amount of a combustible gas in the atmosphere as
20 follows: the decomposition of combustible gas on the catalyst
surface gives out energy which heats the resistance wire, the
increase in temperature causes the resistance of the wire to
increase and so the current flowing through the pellistor
decreases (assuming a constant potential drop across the wire)
25 and this is detected and provides a measure of the amount of the
combustible gas in the atmosphere.

One problem with pellistor operation is that the signal from
a given pellistor (i.e. the change in the resistance of the
pellistor wire for each percent of a gas) is not consistent from
30 gas to gas and 1% methane will give a different reading to, say,
1% xylene; generally speaking the resistance change in a
pellistor for a given percentage of combustible gas decreases as
the molecular weight of the gas increases. This gives rise to two
problems: firstly, it is necessary to calibrate the pellistor for
35 each different type of gas that it is desired to detect and
secondly inaccurate readings will be obtained if two or more

combustible gases are present in the atmosphere being detected.

In the present specification, the percentage of any combustible gas is expressed as the percentage of the concentration of that gas related to its lower explosive limit (LEL). Thus, the LEL is taken to be 100% and, for example a 10% concentration is one tenth of the LEL concentration.

The optimum operating temperature for a pellistor varies from gas to gas and Figure 1 shows the output signal (measured as the current (in mA) flowing through a pellistor) against the normal operating temperature of a pellistor for methane and hexane at a given percentage (40%) of their lower explosive limit (LEL). Thus, if one were operating at a temperature T_3 in order to detect methane and if hexane were in fact present then the output signal would indicate that the amount of combustible gas is lower than in fact it is and the appropriate alarm warning of the build-up of combustible gas may not be triggered.

The object of the present invention is to provide a system which produces an acceptable signal for the major combustible gases (e.g. methane, hexane, acetone and xylene) without requiring separate calibration for each gas.

US 3,531,980, US 3,560,160, US 4,002,429 and GB 1,427,515 described methods of analysing the amount of combustible gases in a sample by catalytically oxidising the combustible gas. The specifications also teach that a resistance wire forming one arm of a wheatstone bridge should be in thermal contact with the catalyst so that the catalytic oxidation of the combustible gas causes an increase in the temperature of the resistance wire thereby altering its resistance and causing a potential difference between the balance points of the wheatstone bridge. The potential difference is integrated over time to provide a measure of the amount of the combustible gas in the sample. One problem with this technique is that it requires an accurate sample of the gas to be taken and the measures necessary to ensure an accurate sample size are often complex. In contrast, the present invention can be used without the need to take samples of accurate size.

DISCLOSURE OF INVENTION

Instead of applying a fixed voltage across the pellistor to maintain the pellistor at a fixed temperature (in the absence of a combustible gas), the present invention deliberately varies the temperature of the pellistor over a range and processes the changing signal received over that range to provide a more accurate reading of the amounts of combustible gases present; in one embodiment we have found that, by choosing suitable temperature ranges, an output signal can be produced that is approximately the same for two or more combustible gases. This is illustrated in Figure 2, which is a graph of the signal from a pellistor (the current flowing through the pellistor) against temperature T for three gases (e.g. methane, hexane and xylene). The areas under the three curves within the temperature range T_1 - T_2 are approximately equal. Thus when the temperature of the pellistor is changed from temperature T_1 to T_2 (or vice versa), and the resulting output signal is integrated, the integrated signal is a measure of the percentage of LEL for each gas (or gas mixture) irrespective of the nature of the gas.

It is evident that the areas under the graphs will not be exactly identical but they will be to an acceptable approximation.

The variation in temperature can be brought about by applying pulses of electrical potential periodically to the pellistors; it is known e.g. from GB- 2,185,577 to heat pellistors using electrical current of pulsed wave form so that the temperature of the pellistor can be altered by changing the frequency or the pulse duration of the waveform. However, in these known cases the frequency of the current is so high that the temperature of the pellistor remains constant and does not change significantly through a cycle. In the present invention, the pellistor temperature must change significantly during the course of a pulse.

According to a second embodiment of the present invention, the change in the resistance of a pellistor can be analysed over the temperature range to provide readings of the amounts of each

of two or more combustible gases in an atmosphere.

Thus, according to the present invention there is provided a method of measuring the amount of combustible gas(es) in an atmosphere, which method comprises:

- 5 (1) contacting the atmosphere with a catalyst for catalysing the combustion of the said gas(es),
- (2) applying a potential difference across a resistance wire that is in thermal contact with the catalyst so as to heat the catalyst to a temperature at which the combustible gas(es)
10 are combusted,
- (3) varying the potential difference being applied across the resistance wire over time thereby varying the operating temperature of the catalyst,
- (4) measuring the change in the electrical resistance of the
15 resistance wire (or a parameter that varies therewith) due to the presence of the combustible gas(es) over at least part of the applied potential range to provide a measure of the amount of combustible gas in the atmosphere.

In accordance with a second aspect of the present invention, there is provided an apparatus for measuring the amount of combustible gas(es) in an atmosphere, the apparatus comprising:

- (1) a catalyst for catalysing the combustion of the said combustible gas(es),
- (2) an electrical resistance wire in thermal contact with
25 the catalyst,
- (3) means for applying a potential difference across the resistance wire to heat the wire to a temperature at which the combustible gas(es) will combust and for varying the applied potential with time, thereby also varying the operating
30 temperature of the catalyst,
- (4) means for measuring over at least part of the applied potential range the change in the electrical resistance of the resistance wire (or a parameter varying therewith) due to the presence of the combustible gas(es) and
- 35 (5) means for calculating from the said electrical resistance change (or change in the said other parameter) the amount of

combustible gas in the atmosphere.

In the present invention, the resistance of the resistance wire can be measured by incorporating the wire/catalyst in one arm of a wheatstone bridge and measuring the voltage between the balance points of the bridge. As will be apparent, it is not necessary to measure the resistance of the wire directly and other parameters that vary in accordance with the resistance, e.g. the current flowing through the wire or the voltage across a wheatstone bridge can instead be measured.

Hereafter in the description, the combined resistance wire and catalyst will, for simplicity, be referred to as a 'pellistor'.

The potential difference across the pellistor is preferably applied cyclically and in the course of each cycle, the temperature of the pellistor will change from a first temperature T_1 to a second temperature T_2 (for a fixed amount of combustible gas in the atmosphere).

Although theoretically it is possible for temperature T_2 to be higher than temperature T_1 , it is preferred that temperature T_1 is greater than temperature T_2 and, in each cycle, the pellistor is allowed to cool from temperature T_1 to temperature T_2 ; if T_2 were higher than T_1 , the pellistor would as it cooled down from temperature T_2 , provide a signal and this could lead to inaccuracies.

It is important that the temperature change between temperatures T_1 and T_2 should be gradual by which we mean that the transition from temperature T_1 to T_2 must not be instantaneous and should be sufficiently long to allow the pellistor to provide signals at temperatures intermediate between T_1 and T_2 but the term 'gradual' is not intended to require that the temperature necessarily changes smoothly between temperatures T_1 and T_2 . It is desirable, in order to provide maximum accuracy, for the frequency of the cycles to be as high as possible and so the time of the transition between temperatures T_1 and T_2 should not be excessive. We have found that a transition time of 1 to 20 ms, e.g. 2 to 10 ms and particularly about 4 ms is sufficient to

provide accurate readings.

It will be appreciated that the temperatures T_1 and T_2 of the pellistor will not usually be known but rather the potential supplied to the pellistor will be varied (usually empirically) to provide temperatures T_1 and T_2 .

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be explained in further detail with the aid of the following drawings in which:

Figure 1 is a graph of the change in the output signal from a prior art wheatstone bridge incorporating a pellistor (measured as the current flowing through the pellistor) against the pellistor operating temperature for methane and hexane at a fixed concentration (measured as % LEL);

Figure 2 is the same as Figure 1 but in respect of methane, hexane, and xylene;

Figure 3 shows a pellistor control circuit for use in the present invention;

Figure 4 shows (a) the voltage pulses supplied by the circuit of Figure 3 to the pellistor and (b) the consequential variation in operating temperature of the pellistor in the absence of combustible gas;

Figure 5 is a graph of the output signal (in mA) from the circuit of Figure 3 against the concentration of methane (measured as % LEL),

Figure 6 shows a second pellistor control circuit of the present invention,

Figure 7 is a graph showing the signal received from the circuit of Figure 6 against current passed through the circuit for an atmosphere containing 40% LEL methane and 40% LEL pentane,

Figures 8 and 9 are graphs showing the signal of Figure 7 resolved into the signal for methane (Figure 8) and the signal for pentane (Figure 9).

The graphs of Figures 1 and 2 have already been discussed above but two further points should be made about these Figures:

(1) It is possible to operate a pellistor to detect two gases so that the output signal per % LEL of each gas is

identical by maintaining the temperature of the pellistor at T_x shown in Figure 1. The problem with this approach is that a small variation in operating temperature (to say T_y) has grave effects on the signal produced by the two gases. The integration of the signal between temperatures T_1 and T_2 (see Figure 2) gives a far lower error when there are slight variations in temperatures. In this connection it should be remembered that pellistors are often powered by batteries in portable detection units and so are prone to slight variations in operating voltage causing errors in the operating temperature of a pellistor.

(2) The choice of temperatures T_1 and T_2 in the graphs of Figures 1 and 2 are obviously important. They can be optimised for any combination of combustible gases that it is desired to detect, but their precise values will usually be set empirically. The difference between temperatures T_1 and T_2 is preferably between 30 and 70°C, e.g. 40 to 60 °C and preferably about 50°C (although the exact difference will of course depend on the shapes of the signal vs temperature graphs for the desired gases). If the temperature variation is excessively high the pellistor wire could melt (or fuse) or the catalyst may be damaged and if it is too low, the pellistor will, in effect, be operating at a constant temperature which does not give the benefits of the present invention.

Referring to Figures 3 and 4, the former shows a circuit for providing the desired temperature changes; the pellistor 10 is incorporated into a bridge circuit connected between a supply rail 12 at 4.4V and earth. A pulse generator 14 of standard, known type which incorporates a field effect transistor, provides a pulsed voltage (shown in Figure 4a) to the bridge; the control of the pulses can be achieved by a microprocessor. Apart from the pellistor, the bridge contains a thermistor 16, which is positioned close to the pellistor, and two fixed resistors 18 and 20 in order to provide temperature compensation. Instead of a thermistor 16, a second pellistor may be used but the second pellistor should not have any catalyst or the catalyst should be poisoned. A capacitor 22 is connected across the bridge to

integrate the signals from the pellistor 10 and the potential across capacitor 22, as measured by a digital voltmeter 24 of high resistance and low impedance, provides a measure signal of the amount of combustible gas in the atmosphere under test, as will be explained in greater detail below. Alternatively, if the voltmeter has a suitable internal capacitance, the capacitor 22 can be dispensed with. As an alternative the current flowing through the pellistor can be integrated and measured.

The pulsed voltage supplied by pulse generator 14 to pellistor 10 is shown in Figure 4a and the variation in the temperature of the pellistor is shown in Figure 4b. Needless to say the exact temperature of the pellistor will increase with increasing quantities of combustible gases in the atmosphere being sensed but the temperature plot in Figure 4b gives a qualitative idea of the variation in the pellistor temperature over a cycle. The difference between the voltages at the beginning and the end of each peak (V_1 and V_2) can in the arrangement of Figure 3 be approximately 10 to 12 mV (from 212 mV to 200 mV) which gives a temperature variation of approximately 375°C (T_1) to 325°C (T_2).

The signal produced by the pellistor is fed to one plate of capacitor 22 while the other plate is supplied with current by the thermistor 16, the potential between the plates being measured by digital voltmeter 24 and gives a measure of the amount of combustible gas present.

If combustible gas is present in the atmosphere around the pellistor, it will be decomposed on the surface of the pellistor causing the temperature of the pellistor to rise, thereby increasing the resistance of the pellistor; thus the voltage drop across the pellistor increases and so the potential supplied by the pellistor to capacitor 22 will decrease; the magnitude of the voltage drop will depend on the amount of combustible gas in the atmosphere under test.

The frequency of the pulses supplied by pulse generator 14 can be varied but we have found that a pulse duration of 4mS with an interval between the end of one pulse and the beginning of the

next of 12.2 mS has proved satisfactory.

The circuit of Figure 6 is essentially the same as that of Figure 3 except the capacitor 22 has been removed, an ammeter 26 is connected to detect the current supplied to the bridge and the output of voltmeter 24 is connected to a microprocessor 30 incorporating an output device 32, which may be a graph-plotter, a display or a printer. The microprocessor 30 can, of course, control the voltage pulses applied at 14 and this is shown in Figure 6. The other elements of the circuit of Figure 6 are the same as the circuit of Figure 3 and the same reference numbers have been used in the two circuits to indicate the same elements.

It will be appreciated that the voltage difference at the voltmeter 24 will provide an approximate measure of the resistance of the pellistor 10 and the current flowing through the bridge (as measured by the ammeter 26) will govern the operating temperature of the pellistor 10.

The apparatus of Figure 6 must be zeroed before it can operate satisfactorily. This is done by exposing the pellistor to an atmosphere containing no combustible gas; pulses of potential of the form shown in Figure 4(a) are applied across the bridge by device 14 under the control of the microprocessor 30. The voltages between the balance points of the bridge (as measured by the voltmeter 24) during the course of each pulse (as measured by the ammeter 26) are stored in the microprocessor 30 as "zero voltages". The pellistor 10 is then exposed to a test atmosphere containing combustible gas and the voltages between the balance points of the bridge (as measured by the voltmeter 24) during the course of each pulse are fed to the microprocessor 30. The zero voltages are then subtracted from the test voltages (at corresponding times of the pulse) to provide voltage values (hereafter called "signal voltages") due to the presence in the atmosphere of the combustible test gas. The zero voltages need only be taken occasionally, e.g. when the apparatus is first switched on.

If there is only one combustible gas in the atmosphere, the amount of this gas can be found either by dividing one of the

signal voltages found in any one pulse, e.g. the maximum signal voltage found, by a signal value representing 100% LEL of that gas or by integrating the signal voltages over the course of part or the whole of a voltage cycle and dividing the integrated signal voltage by a signal value representing 100% LEL of that gas. In either case, the result will be expressed as a percentage of the gas compared to the lower explosive limit of the gas.

If there are two or more combustible gases in the atmosphere, the amounts of each can be found by resolving the graph of the signal voltages over the course of a voltage cycle into graphs for each individual combustible gas and performing the exercise described in the previous paragraph on the individual resolved graphs. The resolution of the signal voltage graph into graphs for each gas can be performed by means of commercially-available computer software. It is not of course necessary for graphs to be drawn but is convenient here to think of actual graphs in order to assist an understanding of these steps. An example of the resolution of a signal voltage graph is given in Example 3 below.

Example 1

The circuit shown in Figure 3 is used to measure the amount of methane in an atmosphere. The pulses produced by the pulse generator have the form shown in Figure 4a with a pulse frequency of 16.2 mS and a pulse duration of 4 mS, with a mean current of 47.7 mA. The results are shown in Figure 5 which is a plot of the current through the pellistor (in mA) against concentration of methane (in % of LEL). Figure 5 shows that measuring the concentration over a range of temperatures and integrating the resulting pellistor output to provide an output signal provides a near linear correlation between output signal and % methane.

Example 2

The experiment of Example 1 was repeated both for hexane and for methane. The results were as follows:

| | | | Theoretical |
|------------|-----------------|---------------------|---------------------|
| | Signal | Hexane/methane | hexane/methane |
| <u>Gas</u> | <u>mA/% LEL</u> | <u>signal ratio</u> | <u>signal ratio</u> |
| 5 Methane | 0.0325 | 1.00 | 1.00 |
| Hexane | 0.0350 | 1.08 | 0.37 |

The theoretical hexane/methane signal ratio shown in the above table is the ratio of the signals that one would normally expect for the two gases using the type of pellistor in the circuit of Figure 3 taken at the optimum temperature for each gas. Thus, it can be seen that by operating according to the present invention the signal to methane is practically identical to the signal to hexane and this allows the same detector to be used without further calibration to measure both hexane and methane and mixtures thereof.

One advantage of the arrangement of the present invention for use with high molecular weight gases, e.g. xylene, is that it prevents the poisoning of the pellistor. High molecular weight gases are usually detected at relatively low temperatures and their decomposition can cause a deposit on the pellistor catalyst surface. Because the arrangement of the present invention operates over a broad temperature range that includes a relatively high temperature, the deposits do not form on the pellistor or, if they do form, they are at least partially burnt off at the high temperatures involved.

Example 3

The pellistor 10 in the circuit of Figure 6 is exposed to an atmosphere containing no combustible gas; pulses of potential of the form shown in Figure 4(a) are applied across the bridge by device 14 under the control of the microprocessor 30. The voltages across the bridge (as measured by the voltmeter 24) applied during the course of each pulse are stored in the microprocessor 30 as "zero voltages". The pellistor 10 is then exposed to a test atmosphere containing methane and pentane each

in an amount of 40% of their respective LELs and the voltage pulses (as shown in Figure 4(a)) are imposed across the bridge. The voltages between the balance points of the bridge (as measured by the voltmeter 24) during the course of each pulse are fed to the microprocessor 30. The zero voltages are then subtracted from the test voltages to provide signal voltages, i.e. voltage changes due to the presence in the atmosphere of methane and pentane.

The signal voltages over the course of a pulse for the above test atmosphere against current (as measured by ammeter 26) are plotted in Figure 7.

It will be observed that the graph shown in Figure 7 has a complex structure. It is possible to resolve the graph of Figure 7 into two component curves shown in Figures 8 and 9 using commercially-available computer software; basically, this is achieved by counting the number of peaks (or inflection points) in the graph and assuming that the graph is made up of a corresponding number of Gaussian curves. This has been done in respect of the graph in Figure 7 to provide a graph (Figure 8) for methane; the graph for pentane (Figure 9) may then be derived by subtracting the graph of Figure 8 from that of Figure 7. The amount of each gas can be calculated either by integrating the resolved graphs (i.e. graphs of Figures 8 and 9) and dividing the resulting integrated values by the corresponding integrated value for 100% LEL of the respective gas or by measuring the maximum signal voltage and dividing it by the corresponding maximum signal at 100% LEL of the respective gas to provide readings expressed as percentages of the LEL.

The above calculations can be performed by the microprocessor 30 without drawing the graphs shown in Figures 7 to 9.

CLAIMS

1. A method of measuring the amount of combustible gas(es) in an atmosphere, which method comprises:

5 (1) contacting the atmosphere with a catalyst for catalysing the combustion of the said gas(es),

(2) applying a potential difference across a resistance wire that is in thermal contact with the catalyst so as to heat the catalyst to a temperature at which the combustible gas(es)
10 are combusted,

(3) varying the potential difference being applied across the resistance wire over time thereby varying the operating temperature of the catalyst,

(4) measuring the change in the electrical resistance of the
15 resistance wire (or a parameter that varies therewith) due to the presence of the combustible gas(es) over at least part of the applied potential range to provide a measure of the amount of combustible gas in the atmosphere.

20 2. A method as claimed in claim 1, wherein the electrical resistance (or the parameter varying therewith) of the resistance wire is integrated over at least part of the applied potential range to provide the said measure of the amount of combustible gas in the atmosphere.

25 3. A method as claimed in claim 2, wherein the atmosphere contains two or more combustible gases and wherein the applied potential range over which the electrical resistance (or the parameter varying therewith) is integrated is
30 so chosen that the integrated resistance per unit amount of each combustible gas is approximately the same as the integrated resistance per unit amount of the or each of the other combustible gas(es).

35 4. A method as claimed in claim 1, wherein the potential difference applied across the resistance wire is varied

cyclically.

5. A method as claimed in claim 4, wherein each cycle is repeated every 1 to 50 milliseconds, e.g. every 5 to 30 milliseconds and preferably every 10 to 20 milliseconds.

6. A method as claimed in claim 4, wherein a potential difference is maintained across the resistance wire for a part only of each cycle.

7. A method as claimed in claim 4, wherein a potential difference is applied across the resistance wire for 1 to 20 milliseconds, e.g. 2 to 10 milliseconds, and preferably for about 4 milliseconds in each cycle.

8. A method as claimed in claim 1 for measuring the amounts of two or more combustible gases in an atmosphere which comprises analysing the change in the electrical resistance (or the parameter varying therewith) of the resistance wire over at least part of the applied potential range and deriving therefrom the resistance change (or the change in the said other parameter) due to each combustible gas and calculating from the said resistance changes the amounts of each gas in the atmosphere.

9. A method as claimed in claim 8, wherein the calculation of the amounts of each gas in the atmosphere comprises taking the maximum resistance change (or change in the said other parameter) occurring over the applied potential range for each gas and dividing the said maximum resistance changes by a predetermined value for each gas concerned, the resulting values giving the amounts of the gases in the atmosphere.

10. A method as claimed in claim 8, wherein the calculation of the amounts of each gas in the atmosphere comprises integrating the resistance changes (or change in the said other parameter) resulting from each gas and dividing the said

integrated resistance changes by a predetermined value for each gas concerned, the resulting values being the amounts of the gases in the atmosphere.

5 11. An apparatus for measuring the amount of combustible gas(es) in an atmosphere, the apparatus comprising:

(1) a catalyst for catalysing the combustion of the said combustible gas(es),

10 (2) an electrical resistance wire in thermal contact with the catalyst,

(3) means for applying a potential difference across the resistance wire to heat the wire to a temperature at which the combustible gas(es) will combust and for varying the applied potential with time, thereby also varying the operating
15 temperature of the catalyst,

(4) means for measuring over at least part of the applied potential range the change in the electrical resistance of the resistance wire (or a parameter varying therewith) due to the presence of the combustible gas(es) and

20 (5) means for calculating from the said electrical resistance change (or change in the said other parameter) the amount of combustible gas in the atmosphere.

25 12. An apparatus as claimed in claim 11, wherein the said calculating means integrates the electrical resistance (or the said other parameter) over at least part of the applied potential range.

30 13. An apparatus as claimed in claim 12, for measuring the amount of two or more combustible gases in an atmosphere, wherein the applied potential range over which the electrical resistance of the resistance wire (or a parameter varying therewith) is integrated is such that the integrated resistance per unit amount of each combustible gas is approximately the same as the
35 integrated resistance per unit amount of the or each of the other combustible gas(es).

14. An apparatus as claimed in claim 11, wherein the said means for applying a potential difference varies the potential cyclically.

5

15. An apparatus as claimed in claim 14, wherein each cycle is repeated every 1 to 50 milliseconds, e.g. every 5 to 30 milliseconds and preferably every 10 to 20 milliseconds.

10

16. An apparatus as claimed in claim 14, wherein the said means for applying a potential difference maintains a potential difference across the resistance wire for part only of each cycle.

15

17. An apparatus as claimed in claim 14, wherein the said means for applying a potential difference across the resistance wire applies the said potential difference for 1 to 20 milliseconds, e.g. 2 to 10 milliseconds, and preferably for about 4 milliseconds in each cycle.

20

18. An apparatus as claimed in claim 11 for measuring the amounts of two or more combustible gases in an atmosphere, wherein the calculating means analyses the change in the electrical resistance of the resistance wire (or a parameter varying therewith) and derives the resistance change (or change in the said other parameter) due to each combustible gas and calculates from such resistance changes the amounts of each gas in the atmosphere.

25

30

19. An apparatus as claimed in claim 18, wherein the calculating means divides the maximum resistance change (or change in said other parameter) detected for each gas over the applied potential range by a predetermined value for each gas concerned, the resulting values giving the amount of the various

35

combustible gases in the atmosphere.

20. An apparatus as claimed in claim 18, wherein the calculating means integrates the resistance change (or change in said other parameter) attributable to each combustible gas over at least part of the potential range and divides the said integrated resistance (or said other parameter) by a predetermined value for each gas concerned, the resulting values being the amounts of the various combustible gases in the atmosphere.

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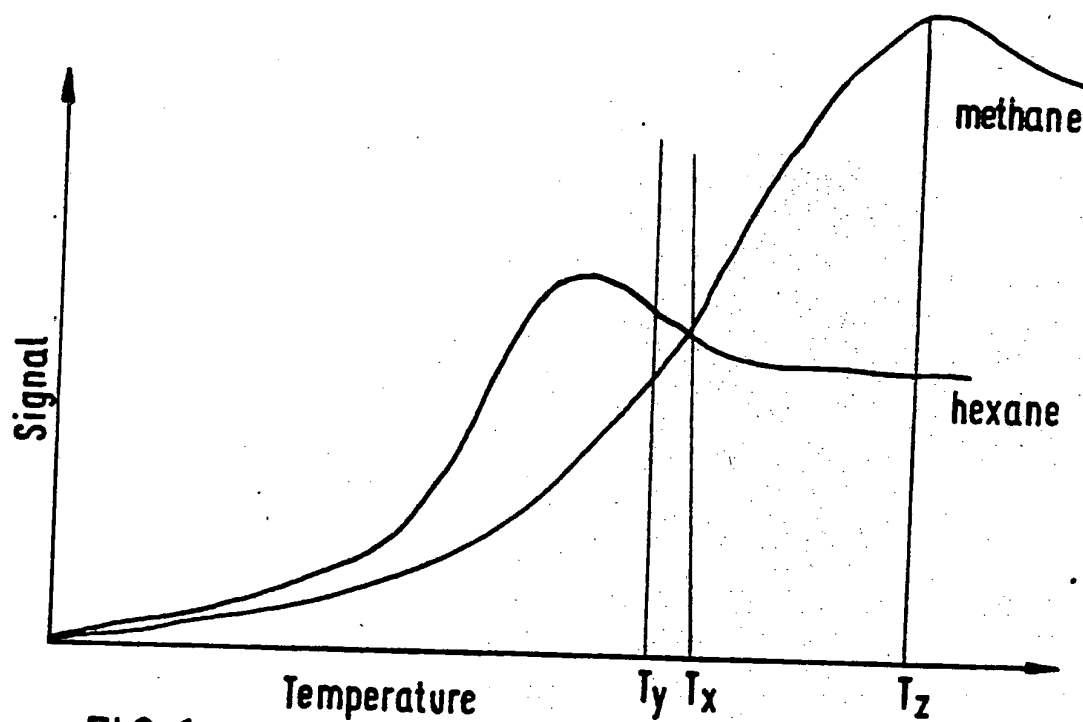


FIG.1

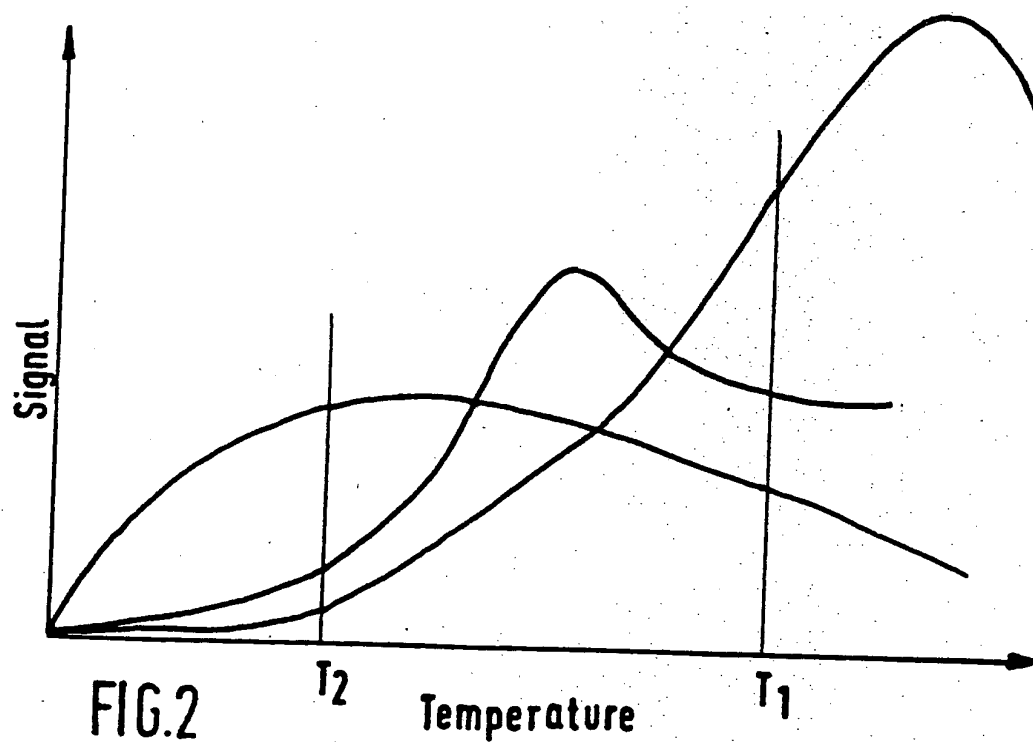


FIG.2

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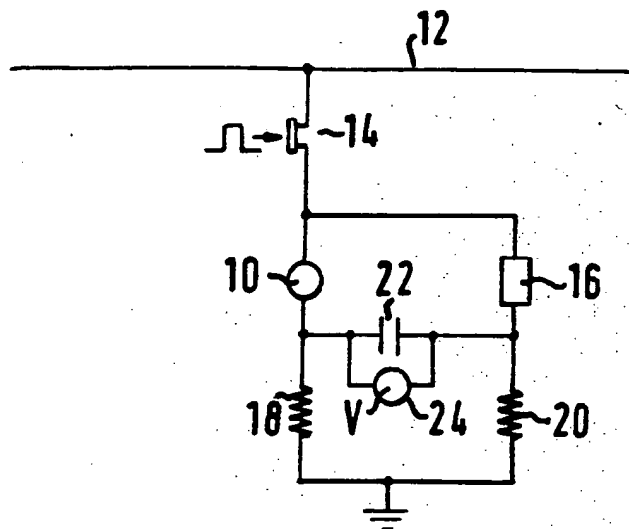


FIG. 3

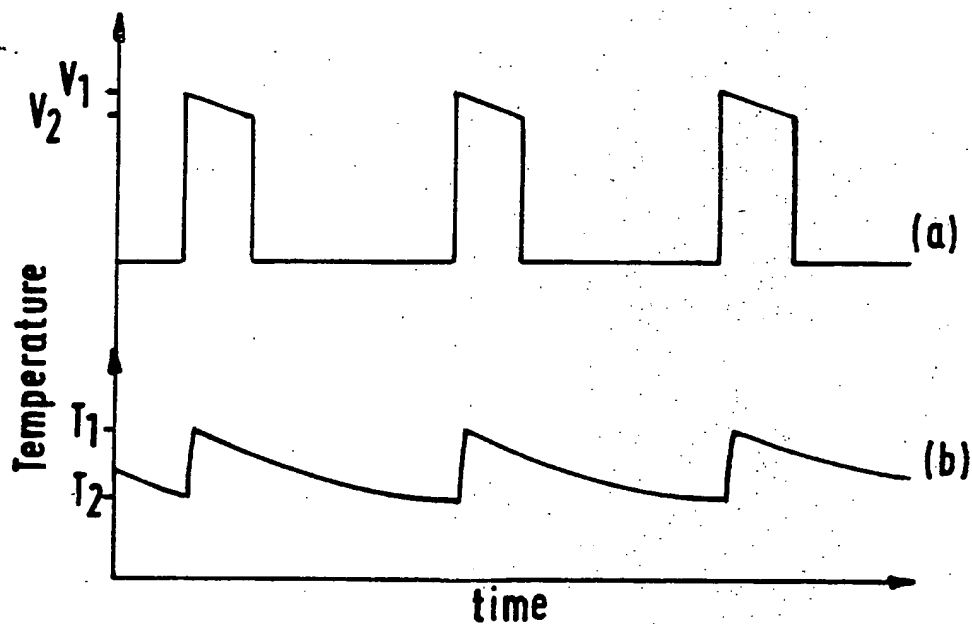


FIG. 4

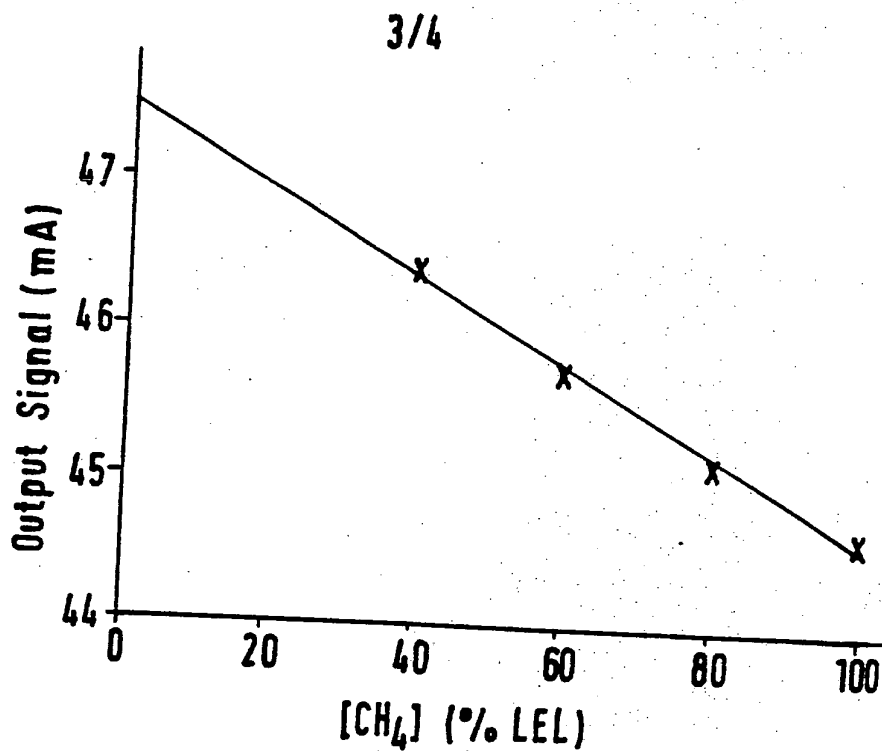


FIG.5

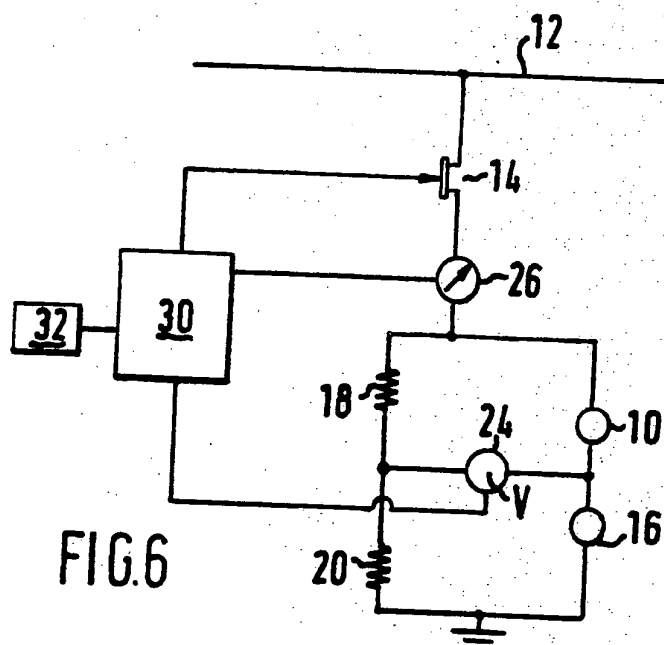


FIG.6

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FIG.7

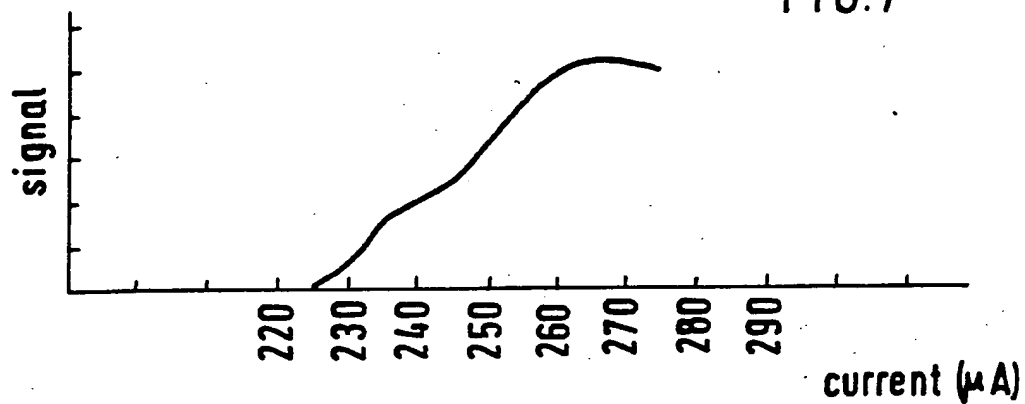


FIG.8

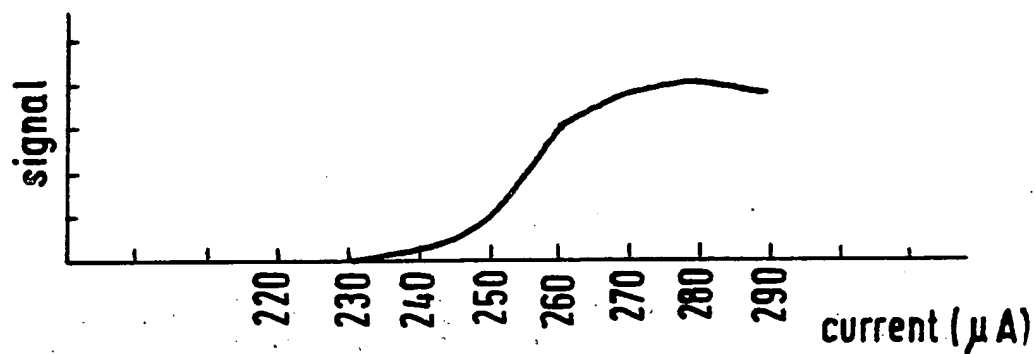
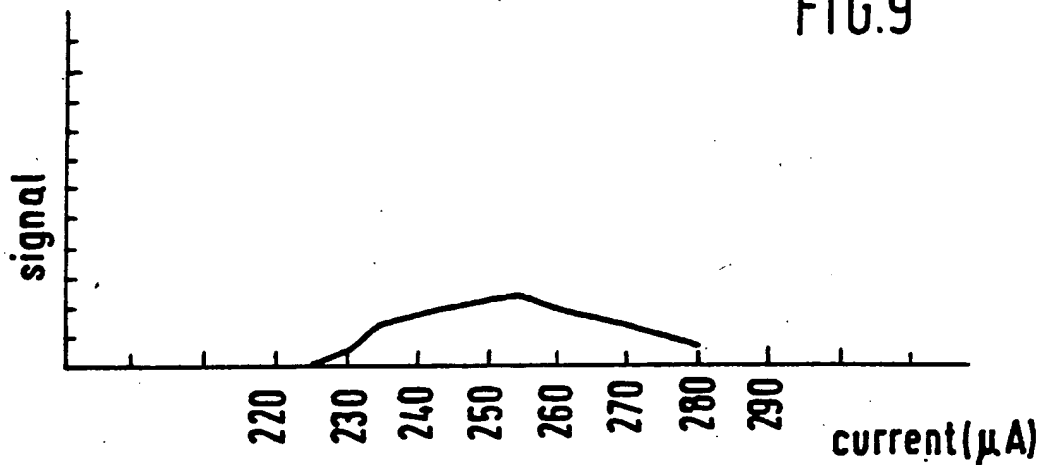



FIG.9



INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 90/01695

| | | |
|--|--|-------------------------------------|
| I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ⁶ According to International Patent Classification (IPC) or to both National Classification and IPC IPC5: G 01 N 27/16, 25/22 | | |
| II. FIELDS SEARCHED | | |
| Minimum Documentation Searched ⁷ | | |
| Classification System | Classification Symbols | |
| IPC5 | G 01 N | |
| Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched ⁸ | | |
| III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹ | | |
| Category * | Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹² | Relevant to Claim No. ¹³ |
| X | US, A, 4627269 (MARTIN FORSTER ET AL) 9 December 1986, see column 6, line 66 - column 7, line 2; column 11, line 1 - line 9; column 13, line 1 - line 15; column 22, line 4 - column 23, line 48; figures 4a,4b,15 | 1,4,8, 11,14, 18 |
| Y | -- | 2,10, 12 |
| Y | US, A, 3531980 (J.A. PENNUCCI) 6 October 1970, see column 1, line 68 - column 2, line 10 | 2,10, 12 |
| | -- | |
| <p>* Special categories of cited documents:¹⁰</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&" document member of the same patent family</p> | | |
| IV. CERTIFICATION | | |
| Date of the Actual Completion of the International Search | Date of Mailing of this International Search Report | |
| 25th January 1991 | 15.02.91 | |
| International Searching Authority | Signature of Authorized Officer | |
| EUROPEAN PATENT OFFICE | F.W. HECK  | |

| III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET) | | |
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| Category * | Citation of Document, with indication, where appropriate, of the relevant passages | Relevant to Claim No |
| P,A | WO, A1, 9012313 (CHARBONNAGES DE FRANCE) 18 October 1990; see abstract; claim 1 -- | 1-20 |
| A | US, A, 4077775 (ROGER LACROIX ET AL) 7 March 1978, see the whole document -- ----- | 1-20 |

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO. PCT/GB 90/01695

SA 41547

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| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---------------------|---|----------------------------------|
| US-A- 4627269 | 09/12/86 | CH-A-B- 668648 EP-A- 0157237 JP-A- 60228950 | 13/01/89 09/10/85 14/11/85 |
| US-A- 3531980 | 06/10/70 | NONE | |
| WO-A1- 9012313 | 18/10/90 | FR-A- 2645646 | 12/10/90 |
| US-A- 4077775 | 07/03/78 | FR-A-B- 2334100 JP-A- 52069694 | 01/07/77 09/06/77 |

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